Development of a new B-Mapping System for SRF Cavity Vertical Tests.

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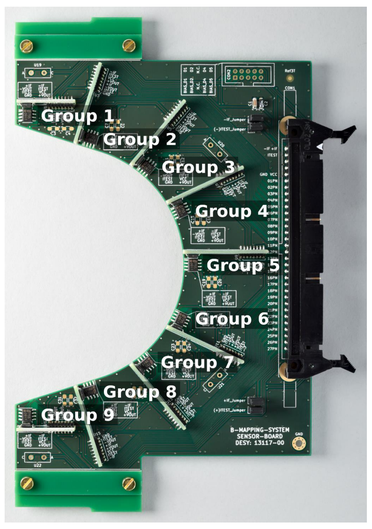
ABSTRACT

Magnetic flux trapped in the Niobium bulk material of superconducting radio frequency (SRF) cavities degrades their quality factor and the accelerating gradient. The sensitivity of the surface resistance to trapped magnetic flux is mainly determined by the pre-treatment, the cavity geometry and the Niobium grain size and orientation. To potentially improve the flux expulsion characteristics and hence the efficiency of future accelerator facilities further studies of the trapping behavior are essential. For this purpose a so-called "B-Mapping System" to monitor the magnetic flux along the outer cavity surface of SRF 1.3 GHz TESLA-Type single-cell cavities is currently under development at DESY. Contrary to former approaches, this system digitizes the sensor signals already inside of the cryostat to extensively reduce the number of required cable feedthroughs.

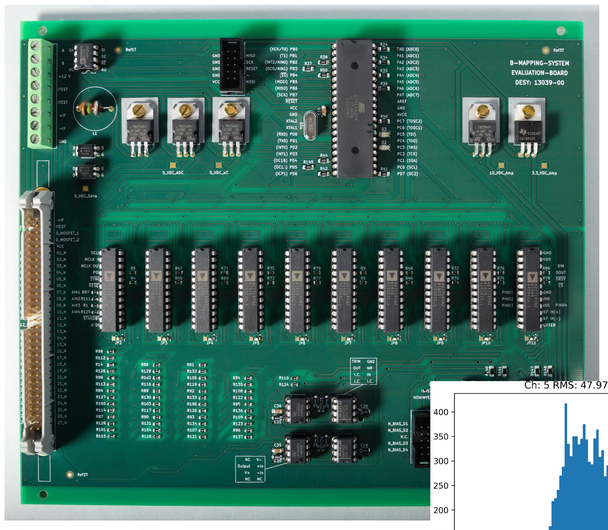
B-MAPPING-SYSTEM: SIGNAL PROCESSING

SENSOR-BOARD

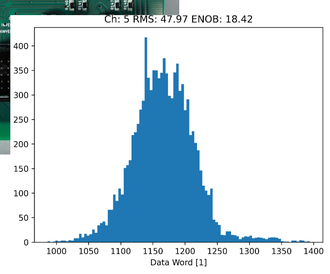


DESY-sensor-board based on B-Mapping approach at Helmholtz-Zentrum Berlin (HZB) using single axis AMR-sensors of type SENSITEC AFF755B. Sensors are arranged in groups of three to enable spatial magnetic flux measurements.

EVALUATION-BOARD



Custom-built 27-channel evaluation-board to digitize the differential output signals of a single sensor-board inside of the cryostat (mounted under the cryostat lid).



SYSTEM OPERATED BY EXTERNAL COMPUTER

DESIGNED TO COVER FULL SENSOR-SIGNAL RESOLUTION:

Effective Number Of Bits (ENOB): 18 (f_s: 50 Hz; Gain: 1)

SYSTEM OVERVIEW:

- **3** AMR-sensors per sensor-group (Group)
- **9** sensor-groups per sensor-board
- **48** sensor-boards ↔ **48** evaluation-boards

Σ **1296** sensors or **432** sensor-groups

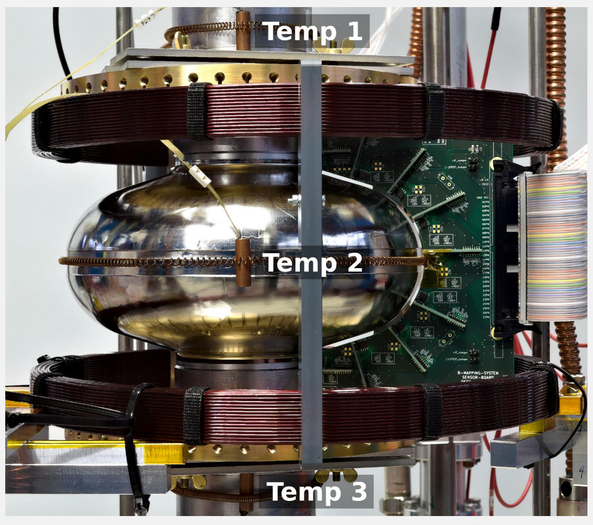
SENSOR SIGNALS DIGITIZED INSIDE OF CRYOSTAT:

- extensively reduced number of feedthroughs
- shorter analog signal lines
- reduced thermal noise

→ enhanced signal-to-noise ratio (SNR)

FIRST PERFORMANCE TEST

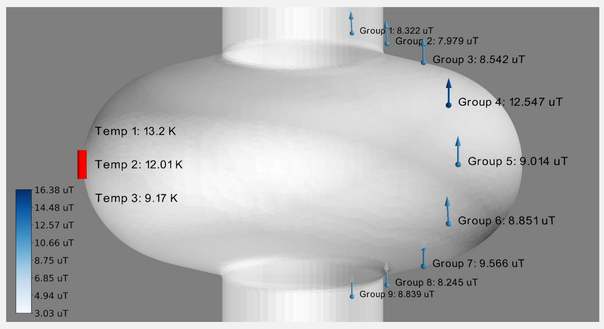
START COOLDOWN (12 K) → **T_c – TRANSITION (9.2 K)** → **STOP COOLDOWN (6 K)**



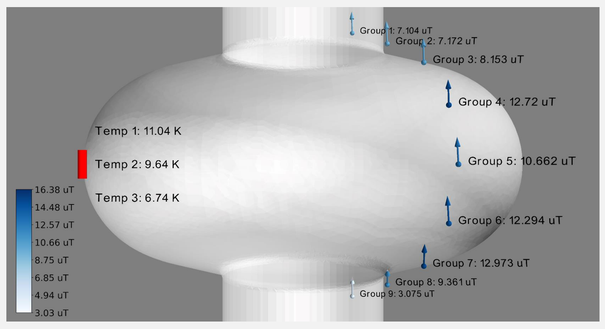
Measurement setup: 1.3 GHz TESLA-Type single-cell SRF cavity (1DE21 – **large grain material**) equipped with a single sensor-board and a Helmholtz coil to apply a magnetic stray field.

SENSOR-GROUP AXIS ORIENTATION:

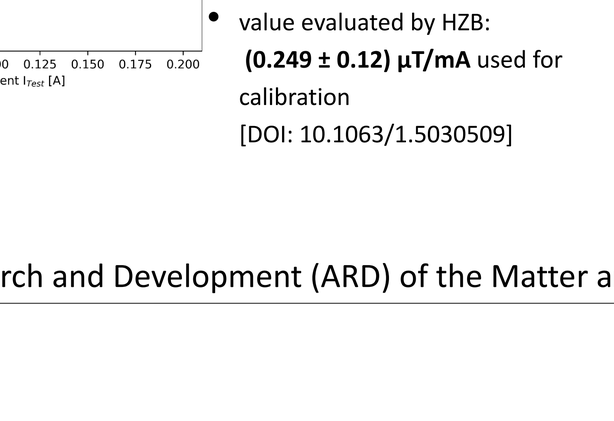
- **X-axis**: perpendicular to sensor-board
- **Y-axis**: perpendicular to cavity axis; parallel to sensor-board
- **Z-axis**: parallel to cavity axis

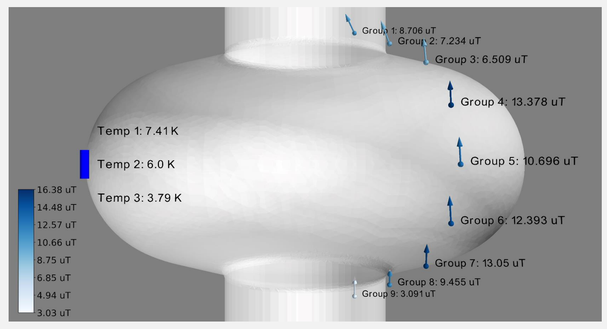


- start of cooldown at **12 K** → **-3 K/h**
- ADC settings: **f_s: 50 Hz**; **Gain: 16**; **bipolar mode**
- applied magnetic flux by Helmholtz coil of **10 µT**
- cavity in normal conducting state
- material completely percolated by magnetic flux



- T_c - transition at equator region (**Temp 2**)
- process of flux expulsion / trapping can be observed in lower half cell (see orientation and absolute value of **Group 5 – 9**)



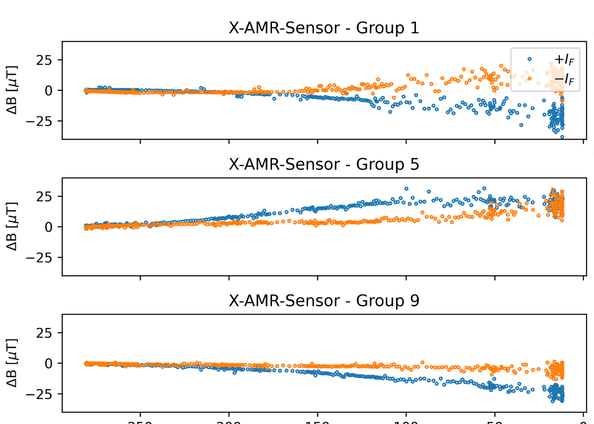


- final state: complete cavity below T_c
- Niobium grain boundary dependent differences in flux trapping / expulsion behavior can be observed by comparing groups in upper and lower half cell

- **"B-Mapping System" successfully tested at temperatures down to 1.8 K**
- **operation without applied stray field possible due to high sensor resolution and very low inherent noise**
- main noise contribution by Helmholtz coil current:
  - → coil in operation: channel dependent **STD σ**: **3 nT** ($\bar{B}$: 2.0 µT) **– 83 nT** ($\bar{B}$: 12.5 µT)
  - → coil switched off: channel dependent **STD σ**: **3 nT** ($\bar{B}$: 59 nT) **– 19 nT** ($\bar{B}$: 449 nT)

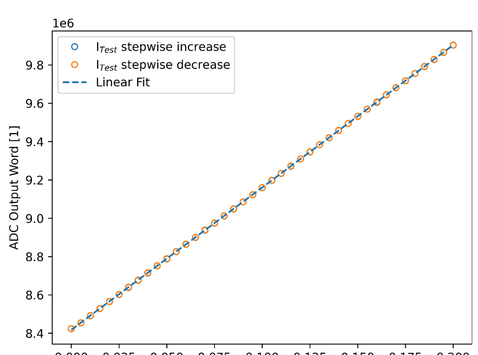
SYSTEM CALIBRATION

RESIDUAL BACKGROUND FIELD:



- system operated with a toggling flip coil current I_F to determine static flux offset
- "random" drift + high **STD σ** observed for low temperatures: **3.4 µT** ($\bar{B}$: 8.7 µT) to **6.5 µT** ($\bar{B}$: 6.5 µT)
  - → HZB findings verified
  - → **offset calibration impossible – spatial residual flux of ~100 nT can not be determined**

SENSOR CALIBRATION:



- sensor included test coils used for calibration:
  - → linear fit to a coil current rise of **0 – 200 mA** (stepw.: **5 mA**)
- high component spread possible according to datasheet: **(0.25 – 0.45) A/m/mA**
- value evaluated by HZB: **(0.249 ± 0.12) µT/mA** used for calibration [DOI: 10.1063/1.5030509]

CONCLUSION

A new approach of a "B-Mapping System" digitizing the differential sensor signals already inside of the cryostat was developed and successfully tested at DESY. The system improves the vertical test environment and enables spatial measurements of the magnetic flux along the outer surface of 1.3 GHz TESLA-Type cavities even without an applied stray field. To improve the accuracy of the AMR-sensor calibration the series connection of the test coils will be separated into independent lines for each axis. Thereby the stray impact from other test coils can be reduced.

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